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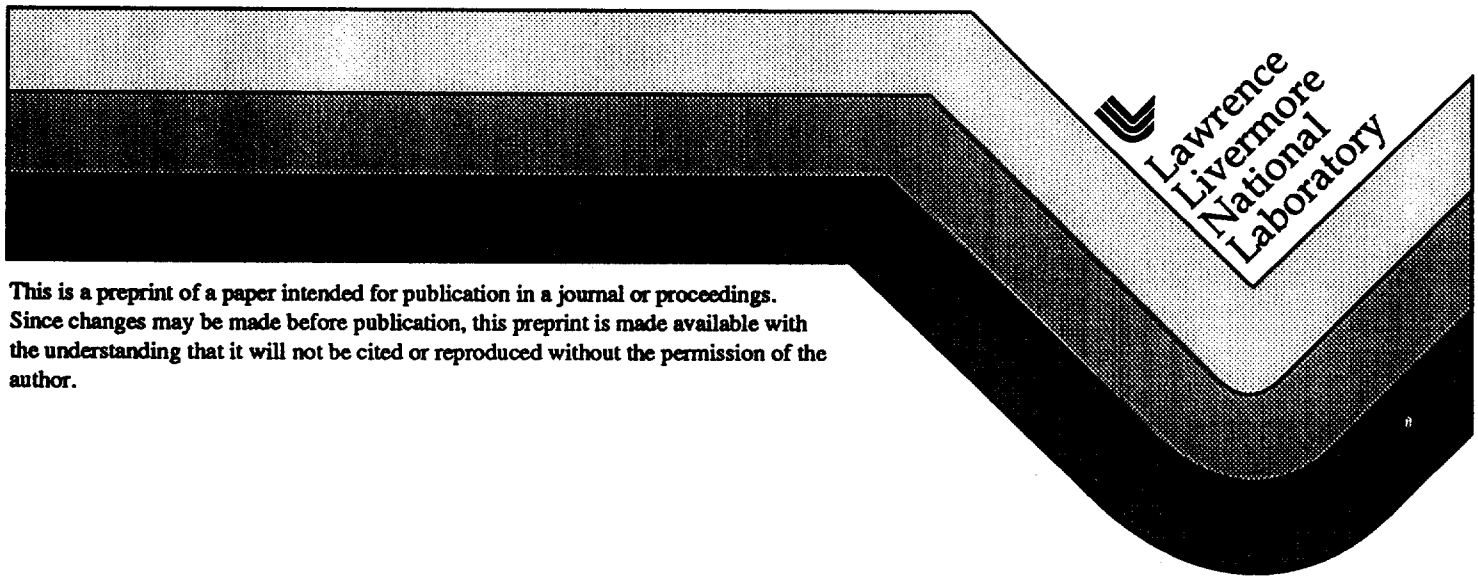

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EMPIRICAL MODEL FOR SHELL-CORRECTED LEVEL DENSITIES

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Abstract
An empirical method for calculating level densities of closed and near-closed shell nuclei has been developed and tested. This method is based on the calculation of shell plus pairing corrections for each relevant nuclide. A new version of the ALICE code is used to extract these corrections from the Myers-Swiatecki mass formula and to apply them to the calculation of effective excitations in level densities. The corrections are applied in a backshifted fashion to assure correct threshold dependence. We compare our calculated results with experimental data for the production of ^{56}Ni and ^{88}Y to test shell corrections near the f7/2 closure and the N=50 neutron shell. We also compare our results with those using pure Fermi gas (plus pairing) level densities, and with the more computationally intensive model of Kataria and Ramamurthy.

1 Introduction

Calculating and modeling nuclear level densities continues to be an important part of modeling nuclear reactions. It has been known for some time that modifications or corrections to level densities due to microscopic effects of pairing and shell structure provide much better agreement between calculations and measured data. Most often this correction is applied as a shift in the excitation energy. The Fermi gas level density model [1] is most often used and works well over a large mass region. However, near shell closure, the Fermi gas model does not agree well with experimental cross sections. A method for applying shell corrections to level densities has been developed and is shown to work well over an extended mass region.

2 Methods

The ALICE nuclear reaction code [2] is being used to test this new shell correction approach. The code uses the Weisskopf-Ewing evaporation model [3]; precompound reactions are calculated using the HMS version [4] of ALICE with improvements that allow for unlimited multiple precompound emission. ALICE also has options to include fission and photon decay channels. A version has been modified to calculate shell-corrected level densities based on the Myers-Swiatecki mass formula [5]. This formula is based on the liquid drop model of the nucleus with algorithms for calculating the shell correction. The pairing correction term used in ALICE is 0 for even-even nuclei, $11/\sqrt{A}$ for odd-even nuclei, and $22/\sqrt{A}$ for odd-odd nuclei, where A is the mass number. The pairing and shell correction terms are combined forming a total microscopic correction which is then added in a "backshifted" fashion to the excitation energy. To ensure correct threshold dependence, the excitation energy of the nucleus having the largest microscopic correction is not shifted. The final corrections to the excitation energies of all other nuclei are shifted (increased) by the difference in microscopic correction energies.

3 Results

Experimental and calculated excitation functions for the $^{59}Co(p,4n)^{56}Ni$ reaction are compared in Fig.1. The solid curve is the calculation with the new shell corrected level density, and the small-dashed curve is the result using the Kataria and Ramamurthy shell correction. The large-dashed curve is the result of using the Fermi gas level density with no shell correction. Note that the Fermi gas curve has been multiplied by 0.1. The experimental data are from Michel et al. [6] and Haasbroek [7]. Fig. 1 demonstrates the strong effect of shell structure at the f7/2 closure. Both of the shell-corrected curves agree reasonably well with the experimental data, whereas the Fermi gas model vastly over-predicts the cross section.

The $^{89}Y(p,pn)^{88}Y$ reaction is used to test the present level density model in a different mass region. Experimental and calculated excitation functions for this reaction are compared in Fig. 2. As in Fig. 1, the solid curve shows the result using the new shell-corrected level density. The small-dashed represents the Kataria and Ramamurthy shell correction, and the large-dashed curve the Fermi gas level density with no shell correction. The experimental data are from Michel et al. [8] and Mustafa et al. [9]. While the new shell-corrected curve agrees reasonably well with experimental data, both the Kataria-Ramamurthy and the Fermi gas curves over-predict the data by about 40% near the peak.

4 Conclusions

An empirical shell-corrected level density model, based on the liquid drop model, has been developed and tested. The model agrees well with experimental excitation functions near the f7/2 shell closure and around the N=50 neutron shell. The fermi gas model (with pairing correction included) does not agree with experimental data, predicting cross sections more than an order of magnitude higher in some reactions. A second shell correction model based on the work of Kataria and Ramamurthy provides agreement with data similar to that of the present model near the f7/2 closure, but predicts higher cross sections than both the data and the present model near the N=50 neutron closure. This new method is simple and physically intuitive, having been derived from the well-known liquid drop model of the nucleus.

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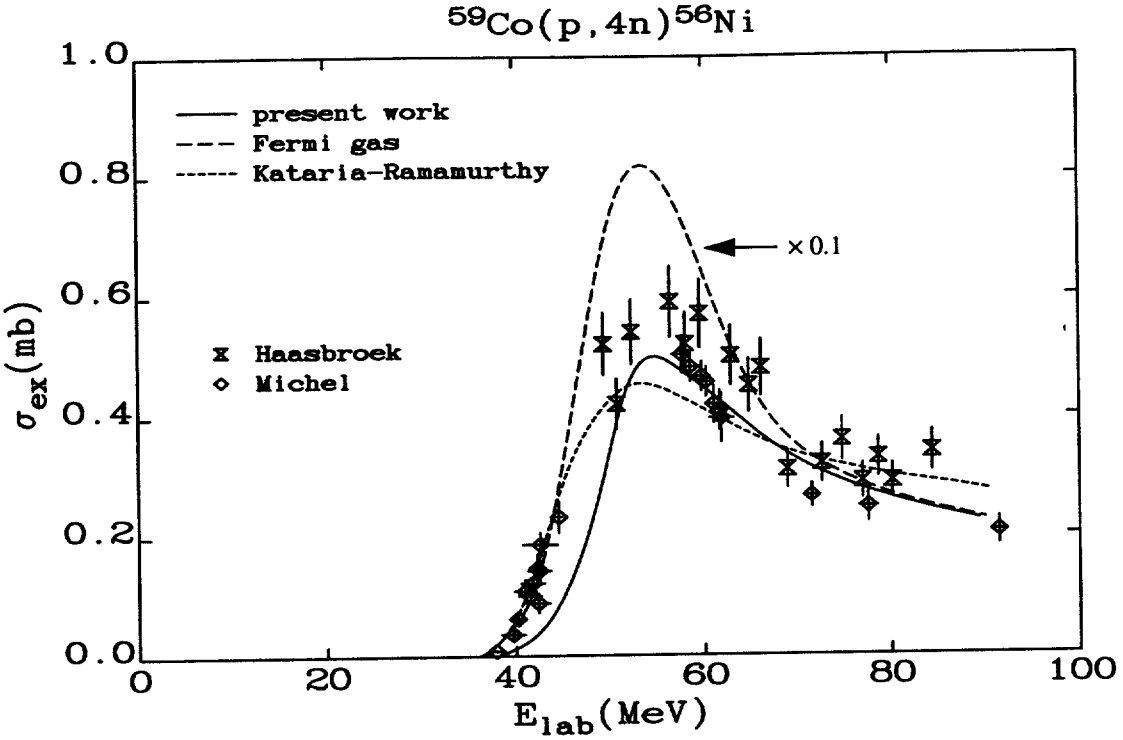

Fig. 1 Excitation function for $^{59}Co(p,4n)^{56}Ni$.

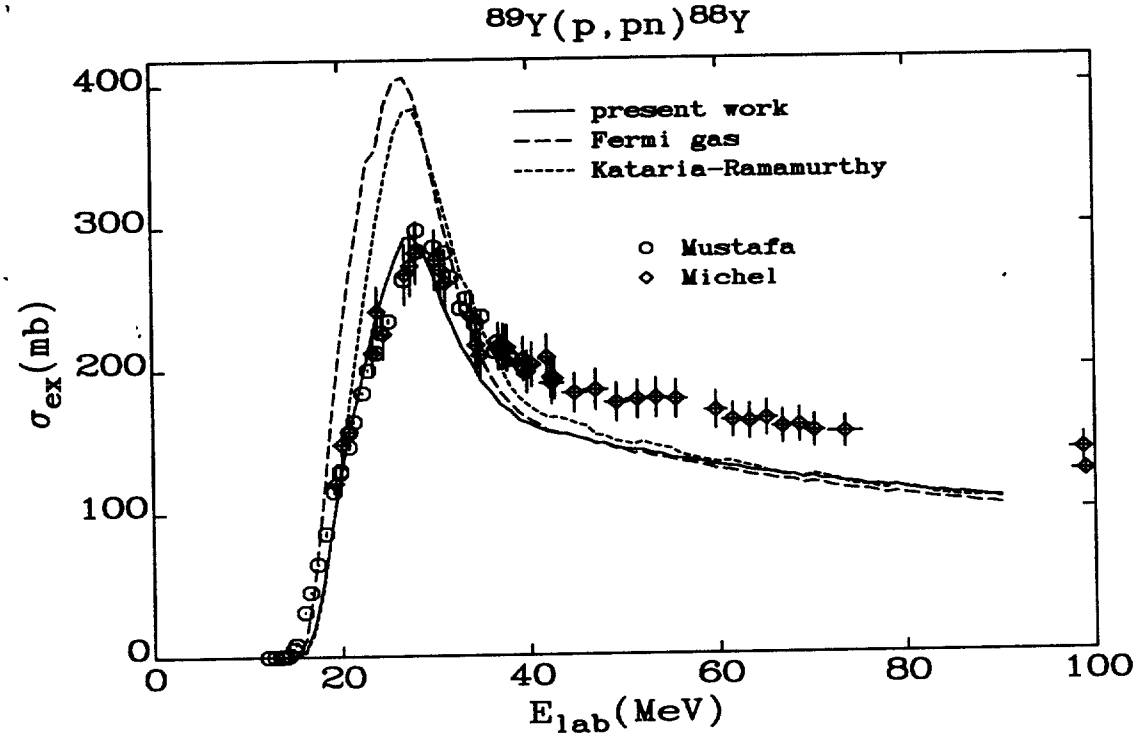

Fig. 2 Excitation function for $^{89}Y(p,pn)^{88}Y$.